rapidly, the characteristics in the latter case might be mistaken to indicate the existence of a frontal structure.

Figure 3 represents a warm-sector cyclone which is increasing in intensity (deepening) with the cold and warm fronts retaining the same positions relative to the moving system. We find that deepening plays an important role in this case and that tendencies would be reported as steadily falling in the warm sector. Unless the deepening is taken into consideration in such a case, the probability is that the warm front would be placed too far south and the cold front too far west.

If the disturbance is occluding rapidly with increasing intensity, as shown in figure 4, we find characteristics behind the cold front that cannot be indicated in our code. The warm sector and warm-front boundary are distinguished by the same characteristics as figures 1 and 3.

The writer has represented all the models as having a northeastward movement. If the reader wishes to consider any other direction it may be done by rotating the diagram the appropriate number of degrees; the characteristics and tendencies will be unchanged.

When considering the tendencies and characteristics as criteria for location of fronts, the forecaster should keep in mind whether the cyclone is increasing, decreasing, or is unchanged in intensity, as well as the direction of movement. If other elements do not necessarily indicate the existence of a front and the tendencies can be explained by the above considerations, then it is highly probable there is no front. In this connection the writer wishes to call attention to cold fronts aloft. In many cases, simple movement of the system will give tendencies which might be interpreted as being associated with a cold front aloft. Therefore, caution should be exercised in locating such a front unless other data, e. g., cloudiness, precipitation, or upper-air soundings, indicate its existence.

It is observed from the models that the deeping or filling tendency is indicated by the 3-hour isallobar (amount of change regardless of characteristic) which crossed the path of the cyclone half way between successive 3-hour positions of the center. While we do not have synoptic maps at 3-hour intervals, many stations do prepare 6 hourly maps on which the deepening or filling tendency obviously will be found one-fourth of the distance between the present center and the location 6 hours before. If the maps are 12 hours apart then the distance will be one-eighth. To determine the amount of tendency at the point in question, the 3-hour isallobars should be carefully drawn and the distance measured accurately.

For example, suppose we have a cyclone with -0.04 tendency one-fourth of the distance from the present center to the position 6 hours before. Then the cyclone should deepen with central pressure 0.16 and 0.32 lower, 12 and 24 hours later, respectively.

This method of computing deepening is valid for occluded cyclones and for warm-sector cyclones which do not occlude during the period for which computation is made.

Warm-sector cyclones on the basis of the above principle will almost invariably show either deepening or unchanging intensities. However, as soon as a cyclone occludes, it usually begins to fill, and deepening should not be calculated beyond the time occlusion is expected to occur.

Computations of deepening or filling are made on the assumption that there will be no change in the rate, which does not introduce large errors unless the time interval is large. Computation beyond a 24-hour period is not recommended.

It has been shown by Petterssen [1] that a pressure system moves normal to the isallobar that passes through the center. Since the pressure tendencies are composed of two parts, that is, partly due to deepening or filling and another part due to movement, we can quickly get a good estimate of the subsequent displacement of the center over a period of 12–24 hours.

In symbols, we have

$$D=N(T_b-T_a)+P_a$$

Where

D=displacement in terms of pressure.
T_b=deepening or filling tendency.
T_a=tendency at the center.
P_a=Pressure at the center.
N=Number of 3-hour periods, e. g., displacement 24 hours hence, $N=8$

The displacement is shown by the point where the pressure D intersects the normal to the isallobar that passes through the center.

Example:

$T_b=0$
$T_a=-0.04$
$P_a=29.68$
$N=8$
$D=8(0+0.04)+29.68=0.32+29.68=30.00$

TEMPERATURE CHANGES IN NORTH AND SOUTH CAROLINA

By EARL C. THOM

[Aerological Division, Weather Bureau, Washington, November 1, 1937]

From a climatic standpoint temperature is generally considered to be of first importance. Hann says: (1) "Temperature is certainly the most important climatic element." All works on climate, meteorology, and forecasting treat the subject of temperature in considerable detail. (2) Much space is given to mean temperature, over various periods of time. Mean maximum and minimum temperatures, diurnal variation, and variations with elevation have been discussed. Tabulations of such temperature items as average departure from normal, greatest daily range, monthly extremes (3), and average 8 a. m., noon, and 8 p. m. temperatures, are to be found (4); but, aside from information on cold waves (5) and two studies on temperature changes affecting Texas (6), little is available treating the subject of changes in temperature from day to day.

This phase of climate is of great practical importance. The daily changes in temperature during any season and especially the occurrence of sudden or unusually large changes affect the plans, habits, and actions of all. The forecasters of the United States Weather Bureau have recognized this and nearly half of all the forecasts have dealt with expected temperature changes.

The Weather Bureau also recognizes the fact that there are differences in the effects of day-to-day temperature changes in the different seasons. During the late fall, winter, and early spring there are more and larger temperature changes than in summer. People become accustomed to larger temperature variations and a considerbly larger change is necessary in winter than in summer to produce the same effects. When stationary temperature has been forecast the change which may occur and still allow the forecast to verify differs with the season, the Bureau having established differing bases for different months for use in temperature verification.

The difference in effects of temperature change is also recognized by the definition of "cold waves." The change which is defined as a cold wave on the extreme tip of the south coast of South Carolina in January would not be considered especially severe in the higher mountains of western North Carolina and would not be out of the ordinary for that month in the north-central part of the United States.

The temperature changes of North and South Carolina during the eight-year period, starting with 1928 and ending with 1935, form the basis of this study. This period was selected because the maps were conveniently available. It is believed that the period is of sufficient length so that conclusions may logically be drawn as to the temperature changes to be expected in these States.

The manuscript maps of the Weather Bureau were used. The changes were taken from the charts on which lines of 24-hour temperature change were drawn, as officially used by the Bureau, and hence were based on "changes" of more than: 6° for June, July, August, and September; 8° for April, May, October, and November; and 10° for December, January, February, and March. "Significant change" when used hereafter has this meaning, viz, a change in temperature from 8 a. m. of 1 day of a month to 8 a. m. of the next day, or from 8 p. m. of 1 day to 8 p. m. of the next, when it exceeds the temperature change defined above for that month. The words "warmer" and "colder" as used hereafter refer to "significant changes".

The a. m. and p. m. temperature charts for each day of the 8 years were studied and notes in tabular form made. Summary sheets and charts were pepared for each month showing the percentage of the time that a stationary forecast would have verified, the percentage of the time it would have been necessary to forecast that the State would be warmer or colder, etc.

In the statements and conclusions which follow, it is to be remembered that they apply to and are characteristic of the particular 8-year period of time coverd by this study. It is not expected that the conclusions would hold without modification if the period were lengthened; it is believed, however, that they set forth information which is of value to the general public and to the student of forecasting.

In general it was found that more significant temperature changes occur in North Carolina than in South Carolina. There was but little difference, morning or evening, in the percentage of the time that *all* of either State was colder or was warmer. The number of cases, however, in which a significant temperature change occurred in part of the State was much greater for North Carolina, both first period (8 a. m. to 8 a. m.) and second period (8 p. m. to 8 p. m.) (figs. 1 and 2).

Taking both States and considering trends of temperature changes it was noted that: (1) the cold season, November to February, was the period when the most significant temperature changes were experienced and it was usually in this period of each year that the maximum of temperature variation, both as to the number of significant changes and their magnitude occurred; (2) the 5 spring and fall months, March, April, May, September, and October, were months of unstable temperature but with both the number of significant changes and the size of them much less than in winter; (3) the summer, June, July, and August, was a period of stability, with few significant temperature changes.

In the cold season (November to February) significant temperature changes in both States are numerous. Had first-period forecasts (8 a. m. to 8 a. m.) of stationary temperature been made every morning, they would have failed to verify 40 percent or more of the time during these 4 months in North Carolina while corresponding forecasts would have failed 27 percent or more of the time in South Carolina (fig. 1). Likewise, second-period forecasts (8 p. m. to 8 p. m.) of stationary temperature in these months would have failed to verify 37 percent or more of the time in North Carolina and 24 percent or more of the time in South Carolina (fig. 2).

As would be expected, significant temperature changes are found to be more frequent in the cold season in North Carolina than in South Carolina, both first and second periods; also, in both States a larger number of significant changes occur in the first than in the second period.

During the years studied, the largest number of significant first-period temperature changes occurs in the month of December. This is true for both States. In December a first-period stationary temperature forecast would fail to verify 56 percent of the time in North Carolina and 40 percent of the time in South Carolina (fig. 1). The month with the second largest number of significant first-period temperature changes occurring in South Carolina is February, when temperature-change forecasts are needed 33 percent of the time.

North Carolina is more likely to get warmer or colder all over the State for the first period in February than in any other month while South Carolina, for the first period, is most likely to be all warmer in February but is most likely to be all colder in November. In the second period North Carolina is more often colder over all the State in November and in January, while South Carolina is most likely to be colder over the whole State only in January. It is quite unusual for all of either North or South Carolina to be warmer for the second period in winter.

The area of most frequent occurrence of significant first-period temperature change is in the northwestern part of North Carolina during November, December, and January and in the northeastern part of the State in February. During the cold season significant second-period temperature changes are more likely in the northeastern part of North Carolina. In South Carolina the area of most frequent occurrence of significant first-period temperature change is in the northwestern part of the State in November and December and in the northeastern part in January and February.

While it is true that in North Carolina the greatest number of significant temperature changes occurred in December, the greatest number of very large changes were recorded in other months. These extreme temperatures change are of especial interest. The percentage of significant first-period temperature changes of more than 20° (twice the significant base) which occurred in North Carolina was 28 percent for December, 39 percent for January, and 50 percent for February; in November 40 percent of all corresponding significant temperature changes exceeded 16°, twice the base for that month. The percentage of those significant first-period changes recorded in this State, which were 30° (3 times the significant base) or more, was 3 percent for December, 8 percent for January, and 9 percent for February, while 9 percent of the corresponding changes in November were over 24°. Two first-period temperature changes of 40° occurred in January and one in February in North Carolina, and two changes of 32° or over occurred in November.

During the cold season abnormally large changes in morning temperature are more likely to occur in North Carolina with falling than with rising temperature. A morning which was colder than the preceding morning by

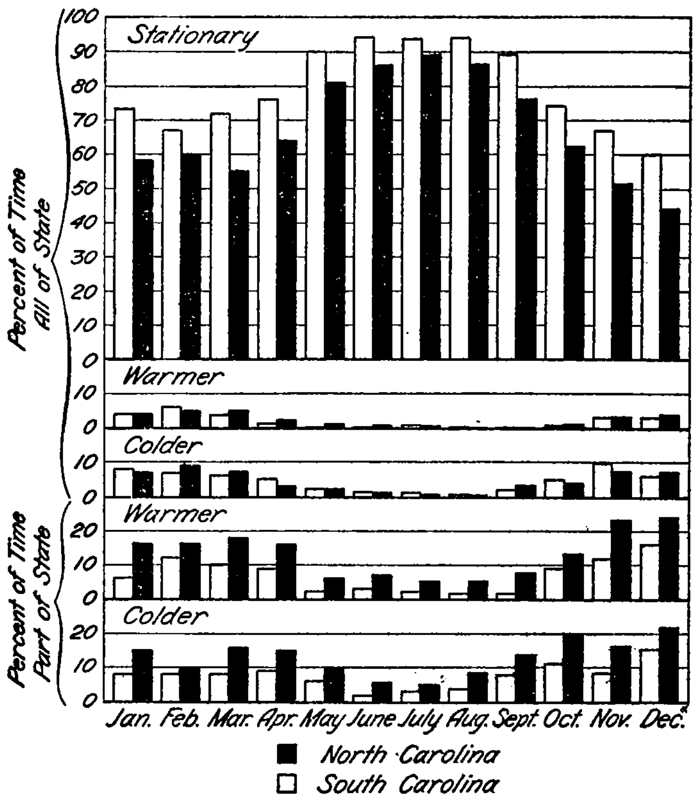

FIGURE 1.—Percentage of the time, 1928 to 1936, that each type of temperature forecast was best for the "first period" (temperature at 8 a. m. of one day compared with the temperature at 8 a. m. of the next day).

three or more times the significant base occurred 20 times during this period while the same amount of change to warmer occurred only 8 times. There were 5 cases recorded during the cold season of the 8 years when the morning temperature was colder by four or more times the significant base and only one case when the same amount of warmer change occurred.

During the 5 spring and fall months temperatures were somewhat unsteady and, in general, more significant temperature changes occurred in March and October than in the other 3 months. In North Carolina a first-period forecast of stationary temperature would have verified 55 percent of the time in March, 62 percent in October, and 81 percent in May (fig. 1). A second-period forecast of stationary temperature for North Carolina would have been good about 52 percent of the time in March and April and about 78 percent of the time in May and September (fig. 2).

During the spring and fall months temperatures are considerably steadier in South Carolina than in North Carolina. A first-period stationary forecast for South Carolina would have verified 72 percent of the time in March and 74½ percent of the time in October, while the same forecast would have verified 90 percent of the time in May (fig. 1). Second-period stationary temperature forecasts in South Carolina would have verified 68 percent of the time in April, 73 percent in March, and 87½ percent in May (fig. 2).

In North Carloina, during the spring and fall, significant temperature changes in both first and second periods are more frequent in the northern half of the State with a somewhat larger number in the northwestern quarter. In South Carolina the significant temperature changes occur with the greatest frequency in the northwestern part of the State.

In both States, spring and fall, the number of significant changes to cooler temperatures was greater than the number to warmer. In the spring months significant second-period temperature changes were of more frequent occurrence in North Carolina than were first-period changes, while in the fall the reverse was true. In South Carolina significant temperature changes are more likely in the second than in the first period during the 3 spring months and during September, while the reverse is true in October.

Summer is the period of steady temperature in both States. North Carolina shows very few significant first-period temperature change in June, July, and August and few second-period changes in July and August. In the 8-year period a stationary first-period forecast would have been best for North Carolina more than 85 percent of the time in summer. A stationary second-period forecast would have been best over 85 percent of the time during the months of July and August only. The largest number of significant changes took place in the northern and western parts of North Carolina, with these changes

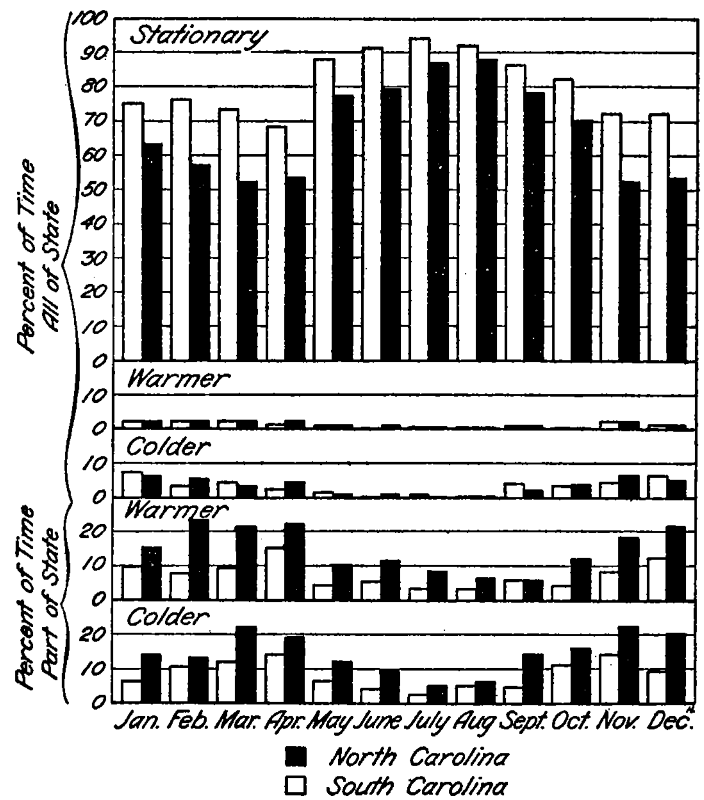

FIGURE 2.—Percentage of the time, 1928 to 1936, that each type of temperature forecast was best for the "second perod" (temperature at 8 p. m. of one day compared with the temperature at 8 p. m. of the next day).

most frequently being noted in the western part and especially at the higher level stations. The number of significant changes recorded in the first and second periods was approximately the same during July and August.

Summer temperatures were even more steady in South Carolina. It appears that for the months of June, July, and August significant temperature changes are unlikely either first or second period, unless decided departures from normal exist, with indications pointing strongly to change in the opposite direction. A stationary forecast for both first and second periods would have been best over 90 percent of the time in June, July, and August. The number of significant temperature changes in South Carolina in the summer was smaller than the number in North Carolina. This was not due to the whole State of South Carolina getting either warmer or colder less frequently, but to the larger number of occurrences in North Carolina when a section of the State showed a significant 24-hour temperature change.

From these statements it can be inferred that rarely is a "colder" or "warmer" forecast needed for South Carolina in the summer and, further, that attempts to forecast significant changes in portions of this State are not likely to be successful during that season of the year. Most of the significant changes that do occur in South Carolina during the summer are in the northern half of the State, with more in the northwestern part than in the northeastern and with these changes occurring most frequently at the higher elevation stations.

CONCLUSIONS

1. This study shows, as would be expected, that significant temperature changes in the Carolinas are most frequent from November to February, are uncommon from June to August, and are, in most months, more frequent in the areas of higher elevation in the western portions than elsewhere in these States. It shows that significant first-period temperature changes may be expected on nearly 6 days out of 10 in the months of November to February in North Carolina, but on only slightly over 3 days out of 10 in the same months in South Carolina; also, that a significant temperature change occurs on only 1 day out of 10 in the summer, first or second period, in these two States. It is found that large changes are more likely to occur with falling than with rising temperature.

2. This study has dealt only with significant temperature changes within 24 hours (first period, 8 a. m. to 8 a. m., and second period, 8 p. m. to 8 p. m.). Many smaller changes, and some larger changes occurring at other hours, have not been considered. It is believed, however, that the data offered are of interest to the general public, showing an important characteristic of the climate of North and South Carolina. Such data are helpful to the forecaster.

LITERATURE CITED

(1) Hann, Julius, Handbook of Climatology, pt. 1 (Tr. by Ward), p. 6.

(2) For examples of extended treatment of temperature see:
Shaw, Sir Napier, Manual of Meteorology, vol. II (1936). ch.IV.
Hann, Julius, Handbook of Climatology, pt. 1 (Tr. by Ward), chs. I, VII, XII, XIV, and XV.

(3) Climatological Tables, MONTHLY WEATHER REVIEW.

(4) United States Meteorological Yearbook, Weather Bureau.

(5) Cox, H. J., Weather Forecasting in the United States, ch. VI.

(6) Tannehill, I. R.:
Severe Cold Waves on the Texas Coqst. MONTHLY WEATHER REVIEW, February 1928, pp. 41–46.
Recovery from Subnormal Temperatures. MONTHLY WEATHER REVIEW, September 1928, pp. 363–367.

NOTES AND REVIEWS

I. R. TANNEHILL. *Hurricanes, their Nature and History.* Princeton University Press, 1938.

This book, by the Chief of the Marine Division of the United States Weather Bureau at Washington, deals particularly with the tropical cyclones of the West Indies and the southern coasts of the United States; however, it includes in nontechnical form the essential facts about tropical cyclones in general. The book contains a large amount of information that is not otherwise accessible except in numerous scattered publications, many of which are now difficult to obtain, and in official records.

The introductory chapter is a general description of the principal phenomena of tropical cyclones and of the methods by which information concerning them is obtained. The following six chapters contain detailed discussions of the winds in the hurricane; the destructive storm waves which frequently accompany hurricanes along the coast; facts and theories relating to the origin and maintenance of the hurricane; the tracks followed by the West Indian hurricanes, with charts showing the tracks of all tropical cyclones known to have been of hurricane intensity from 1874 to 1933, inclusive; rainfall and barometric pressure in tropical cyclones. Chapter 7 is an account of the precursory signs of an approaching hurricane. The destructive effects of hurricanes are described in chapter 10; and chapter 11 discusses precautionary measures on land and sea by which losses of life and property may be reduced. Chapter 9 is devoted to statistics of the annual frequency of West Indian hurricanes.

In chapter 8, discussions are given of the tracks of five hurricanes which followed abnormal paths. The remaining four chapters are essentially a history of all tropical storms of record in the West Indian region from 1493 to 1937, including detailed accounts of many of the most memorable storms, chronological lists, and a year-by-year account, with charts, of all storms during the 20th century.

A brief bibliography and an index complete the volume. —*Edgar W. Woolard.*